Ground Control Data for Aerial Survey of Western Alaska

FINAL PRODUCT REPORT

State of Alaska
Department of Natural Resources

ASP #10-15-047

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INTRODUCTION

This final project report has been produced by RECON LLC (RECON) for the Alaska Department of Natural Resources (DNR) under project contract ASP 10-15-047, providing Ground Control Data for Aerial Survey of Western Alaska.

1.0 PROJECT OVERVIEW

RECON's scope of work under ASP 10-15-047 is to obtain an accurate and useful database of ground control points (GCPs) along the western coastline of Alaska, according to the criteria described in the project contract. DNR's Division of Geological & Geophysical Surveys (DGGS) intends to use this network of GCPs, including check points and benchmark ties, to verify the accuracy and quality of coastal orthoimagery and topographic data to be acquired by DNR in 2015. DNR's overall goal in the acquisition of these data is to improve the ability to orthorectify future products of aerial imaging to be acquired in Alaska's coastal regions, which products may be used as resources for conducting critical tasks such as emergency support, community planning, and environmental monitoring along the coast and within coastal communities. The project's area of interest (AOI) follows approximately 3,500 km of Alaska's western coast from Bering Strait to Kuskokwim Bay (see Appendix A – Map of Area of Interest). DNR has contracted with Fairbanks Fodar to provide aerial imagery products immediately related to this control survey, using structure-from-motion (SfM) technology.

The Final Point Summary included in the Final Products should be used for final control and orthorectification of aerial imagery products and for publication as DNR sees fit.

2.0 PROJECT METHODOLOGY

RECON's general methodology has been developed over time to support several successful surveying and mapping projects involving a variety of traditional remote sensing technologies. This survey methodology and GCP selection criteria have been adapted to suit the particular needs of the DNR ground control project scope and to meet the project specifications as defined by the contract. All survey work supporting this project was performed directly by or under the supervision of a Professional Land Surveyor registered in the State of Alaska. RECON subcontracted with Hattenburg Dilley & Linnell, LLC (HDL), and JOA Surveys, LLC (JOA), to assemble a strong and experienced survey team to complete the project within DNR's specified timeframe.

2.1 Project Execution Plan

RECON submitted the official Project Execution Plan to DNR on 11 August 2015. The plan was developed in coordination with the DGGS Project Technical Manager, Nicole Kinsman, who reviewed and approved the plan with only two clarifications: 1) ellipsoid height was added as a data item to be provided in the Preliminary Coordinate File, and 2) it was confirmed that sufficient documentation would be provided in the Final Report to identify ground control features.

In general, project methodology conformed to the specifications of the Project Execution Plan as approved. Any subsequent deviations from the methodology have been described in the appropriate section of this Final Report.

2.2 Field Operations

Field work was completed within the expected schedule and with no significant issues. Field activities commenced on 15 August 2015 and concluded on 14 September 2015. Field survey was conducted by three task forces made up of personnel from RECON, HDL, and JOA, as described in the Project Execution Plan:

- Developed Area Sites, Northern Region (Brevig Mission to Unalakleet)
- Developed Area Sites, Southern Region (Saint Michael to Kongiganak)
- Remote Sites, Entire Region

Logistics of accommodations, fuel supply, and other resources were organized in advance by RECON staff. Major support hubs included Bethel, St Mary's, Unalakleet, and Nome, as expected. In the interest of community outreach, RECON developed a brief written description of the project goals and basic methodology, which permitting staff used in their advance communications with landowners and which field personnel distributed as needed while traveling throughout the AOI.

Personnel working in the developed areas used a combination of scheduled air travel and chartered fixed-wing travel to reach survey sites. Personnel working in the remote sites used a light helicopter to reach survey sites. This approach worked very well, and field personnel and pilots paid close attention to active weather patterns in their respective region, focusing each day's work in the area where weather-related delays were least likely to impact progress.

2.3 Survey Procedure

Field personnel surveyed 67 photo-identifiable GCPs along the coast, with at least one GCP in each of the 25 developed areas identified in the contract. A total of 81 check points (including GCP bases) were surveyed throughout the AOI, including at least 2 within 5 km of each of the 25 developed areas. A total of 27 GNSS ties to tidal benchmarks were surveyed. Ties were made to three or more existing tidal benchmarks in Lost River, Elim, Hooper Bay, Nome, Toksook Bay, Shaktoolik, and Nunam Iqua. Ties were made to two existing tidal benchmarks in Teller and Unalakleet, because only two tidal benchmarks were suitable for GPS occupations. Positioning was tied to CORS stations as outlined in Section 3.0 (Data Processing). Maps of the general location of GCPs are included with the final deliverables. All in all, the total number of points surveyed was more than the project contract required.

All GCPs surveyed under this contract were spaced in intervals no greater than 50 km. It may be worth noting that the northernmost GCP in RECON's project scope was located at the area of Lost River, taking advantage of the opportunity to acquire GPS at additional existing tide stations there. RECON understands that DGGS intended to survey a GCP in Wales, in support of similar project goals but independent of RECON's project scope. RECON estimates that the GCP at Lost River is approximately 49.6 km (straight-line distance) from the approximate village center at Wales, so depending on where the DGGS GCP is located, the interval between those two points may be slightly greater than 50 km.

RECON discussed survey methodology with Fairbanks Fodar and made every effort to define our GCP site criteria in a way that complemented their data acquisition plan using SfM technology. In any cases of uncertainty, RECON employed the method that would best reflect the intent of DNR's scope and specifications as defined in the project contract for the ground control survey.

2.3.1 Selection of Photo-Identifiable GCPs

Community-based GCPs were used as often as possible. Site selection efforts utilized existing imagery and topographic data to locate GCPs within villages, focusing on photo-identifiable locations at or near airstrips, schools, or DOT facilities in the communities. Examples of these photo-identifiable points include: historical photo panels, sidewalk corners, asphalt and concrete aprons, basketball courts, boardwalks, concrete transformer bases, etc. A permanent survey monument appropriate for the site conditions was set as required.

For GCPs in remote areas between communities, RECON selected sites based on image and topographic interpretation of historic beach ridges above debris line, "high" points in the Yukon-Kuskokwim Delta region, and rock outcrops in the northern region. In the Yukon-Kuskokwim Delta region, RECON's strategy was to gain an aerial view and identify "micro-features." Where no photo-identifiable points exist, RECON field surveyors set a permanent survey mark with a 40 cm x 40 cm aluminum plate appropriate for site conditions. Some plates remain as permanent monuments, and some were removed at the conclusion of the field season when requested by the landowner. Due to the necessity of establishing new photo-identifiable features (such as aluminum plates) in especially remote areas, RECON periodically informed Fairbanks Fodar of the field survey progress in an effort to coordinate the SfM data acquisition with the actions of the field surveyors.

GCPs will be identifiable from aerial or satellite photos with ground sampling distances between 0.2 m and 1.0 m. All permanent survey marks were marked with the project identifier (WAK015) and GCP code. All GCPs were documented with photos as described in Section 2.3.2, and all remote GCPs were further documented with a low-level oblique photo and field sketches to aid in imagery identification.

2.3.2 Data Acquisition

Project data were collected using dual-frequency static GPS receivers. At each GCP or GCP base, a single point was selected as the primary control station. This primary control station had a minimum of two 4-hour sessions of data collected. In cases where a permanent monument was not able to be set or was impractical to set at the GCP, a GCP base monument was set and the GCP was surveyed with RTK or fast-static sessions. When possible, the GCP and tidal benchmarks were occupied in two 4-hour sessions on each mark, with longer sessions if conditions allowed. Occupations used a combination of fixed-height tripods or tripods and rods with bipods, with each occupation at a different height than was used previously at the same point when not using a fixed-height rod. The height of the antenna was measured vertically from the survey mark or geographical feature to the bottom of the antenna. Data was collected at 15-second epochs at all occupations. Check points were acquired using static, real-time-kinematic (RTK), or fast-static techniques collected at the beginning and ending of GCP or GCP base occupation.

At each GCP, GCP base, or tidal benchmark session, the observer completed a GPS field form citing the name of the point, the antenna height, the measurement point, start time, stop time, antenna type, personnel, a site description, and a site sketch. These Field Survey Forms were developed by and are owned by JOA Surveys. In addition, the observer obtained detailed photographs of the point surveyed, including the following views: from standing height, horizontal image(s) showing the tripod relative to the vicinity, the antenna model, the antenna height, and a legible sign identifier of each set monument.

2.3.3 Equipment and Software

Project data were collected using dual-frequency static GPS receivers. Processing methods and software are described in Section 3.0.

The following equipment models were used by field surveyors:

- Leica: 1200, GS10, GS14, GS15
- CHC: OPUS X90-D
- Topcon: Hiper II, Hiper V2

2.3.4 Spatial Reference Framework

RECON complied with the spatial reference framework established in the contract, using the following specifications:

- Vertical Datum: NAVD 88, using the GEOID 12B model
- Horizontal Datum: NAD 83 (2011) epoch 2010.00
- Projection: UTM (zones 3, 4 within AOI)
- Units: Meters

3.0 DATA PROCESSING

GPS observations were processed using OPUS Projects, the latest GPS processing software from the National Geodetic Survey (NGS). OPUS Projects is a web-based online processor, so the user is not responsible for any software installation, maintenance, setup, and dependencies, and this reduces the likelihood of processing inconsistencies or errors. OPUS Projects uses the latest NGS PAGES baseline processing software which is required for publication by the NGS. The trained user sets up a project and assigns the project a code, which is used by the field crews to upload static GPS observations to the appropriate project. For this project in western Alaska, the field crews populated OPUS Projects with their data using the code WAK015.

The processing approach was based on Dr. Gerald L. Mader's approach of relative positioning with HUB and Distant CORS. Dr. Mader recommends a maximum baseline length of 100km from the hub to the furthest point in the network, but a 100km baseline length in western Alaska would require the installation of dozens of base stations in remote locations with limited accessibility. To make this project viable, the Data Manager extended the baseline length to 150km as stated in the Project Execution Plan. Due to a gap in the Yukon-Kuskokwim Delta region, the existing CORS network does not provide coverage for baseline lengths of <150 km throughout the entire project area, and this gap was filled for the purposes of this project by installing a temporary GNSS base station in Emmonak. The base station consisted of a GNSS antenna mounted to a building roof. The antenna and receiver were connected to a laptop via USB and serial adapter cable. The receiver logged data every 30 seconds and wrote a data file every 24 hours to an FTP server. The Distant CORS is one which is more than 1000 km from the HUB CORS. The use of a Distant CORS helps to stabilize the tropospheric corrections. Long observations (>24 hrs) reduced mutual visibility issues at the two CORS. The HUB CORS provided the relative positioning.

Initially, the entire project was conceptualized as a single GPS processing project. However, the three task forces in the field did not observe GPS simultaneously in the same 150km region due to a number of logistical factors and project needs. The resulting baseline sessions would not allow for a single hub processing schema. Processing was initially conducted by carefully selecting observations within 150km of a CORS, and then processing other points for the same session in a different processing scenario, but this method was troublesome due to the volume of data and the multitudes of sessions. As a productive solution, the single project in OPUS was translated into six smaller projects, each with points within a 150km radius of the nearest CORS or the base in Emmonak. The respective GPS observations were uploaded to each of the six projects for processing as originally anticipated.

Prior to baseline processing, either IGS station WHIT in Whitehorse, Yukon Territory, or IGS station FAIR in Fairbanks, Alaska, was brought into each project to better resolve the tropospheric conditions. Data was processed in a radial method, with the nearest CORS being the only hub station. The exception is the base station installed at Emmonak. All of the remaining CORS plus the IGS station were included in the processing. Piecewise continuous tropospheric models were used in the processing.

OPUS Projects has defaults of 0.020m peak-to-peak horizontally and 0.040m vertically. This threshold had to be increased to 0.035m horizontally, while the vertical threshold remained the same. OPUS Projects also has defaults of 80% of the observations and 80% of the fixed integers, both of which had to be reduced to 70%, the minimums for OPUS Shared. All stations met the modified minimums with the exception of OME5, which used 63.8% of the observations in the processing.

When processing was complete for each of the six projects, adjustments were performed using GPSCOM, a Helmert blocking program within OPUS Projects. A free adjustment was first made constraining only the nearest CORS. A constrained adjustment was then performed constraining all CORS positions. No vertical constraints were applied as none of the stations observed were vertical marks. A TIGHT constraint was applied to all CORS, as NGS currently is having problems with the NORMAL constraint. With the TIGHT constraint, the CORS are fixed at the sub-millimeter level of their published positions. All adjustments came out favorably, with millimeter-level correction to the positions.

3.1 Quality Control

All field personnel adhered to the methodology and field procedures listed in the Project Execution Plan. The Lead Surveyor and Survey Manager held conferences with field personnel prior to mobilization to discuss and clarify methodology, and each team member had opportunities to review the document. The field techniques followed NGS Technical Memorandum 58: Guidelines for Establishing GPS Derived Ellipsoid Heights (Standards: 2 cm and 5 cm). Predetermined point and file naming conventions along with form, photo, and field book structure were defined prior to survey and were followed by all field personnel.

4.0 DELIVERABLES

Items deliverable to DNR were completed according to the schedule and specifications defined in the signed contract. All items were delivered in soft copy (digital) format, with hard copies of reports available upon request.

- **Project Execution Plan**: 11 August 2015
- **Monthly Reports**: 31 August 2015, 30 September 2015, and 15 October 2015
- **Preliminary Coordinate File**: 30 September 2015
- **Final Products**: 15 October 2015

The Final Point Summary included in the Final Products should be used for final control and orthorectification of aerial imagery products and for publication as DNR sees fit.

4.1 Final Product Deliverables

This report document is delivered with several attachments in fulfillment of the contract requirements. Following is a list of deliverables as organized by RECON and provided in digital folders.

1. Report – description of the completed project, survey methodology, and data processing
2. Data Dictionary – outline of data delivered and file naming scheme
3. Digital Photos – record photographs of survey sites (as described in Section 2.3.2)
4. RINEX Files – survey data files
5. Field Notes – PDF scans of original field notebooks (as described in Section 2.3.2)
6. Location Maps – reference maps of as-surveyed points
7. Processing Summary – summary of processing information
8. Final Point Summary – XLS file of final point locations for GCPs, check points, and tidal bench marks

SUMMARY

RECON appreciates the opportunity to provide ground control surveying services to the Alaska Department of Natural Resources. With any comments on this report or the overall project, please contact Megan Ross at 907-746-3630 or megan@reconllc.net.

LIST OF ATTACHMENTS
(SEE FOLDERS)

02 – Data Dictionary

03 – Digital Photos

04 – RINEX Files

05 – Field Notes

06 – Location Maps

07 – Processing Summary

08 – Final Point Summary